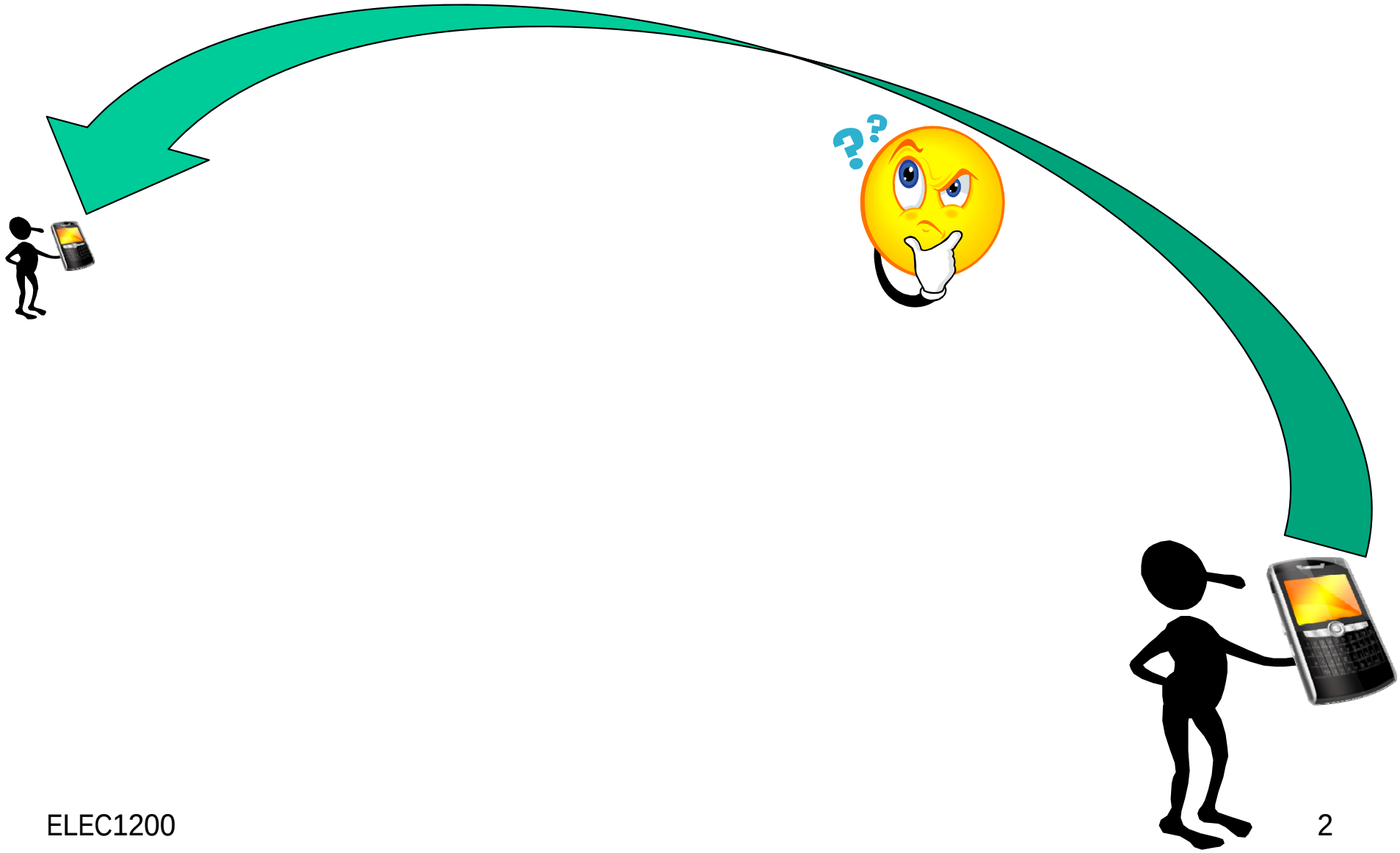
Introduction to Networks

Lecture 18

- What is a network?
- Hierarchy of networks
- Network core
- Packet/circuit switching
- What's a protocol?
- Network structure and Layering

The slides are adapted from ppt slides (in substantially unaltered form) available from "Computer Networking: A Top-Down Approach," 4th edition, by Jim Kurose and Keith Ross, Addison-Wesley, July 2007. Part of the materials are also adapted from MIT 6.02 course notes.

Our Question: How to transmit information from end to end



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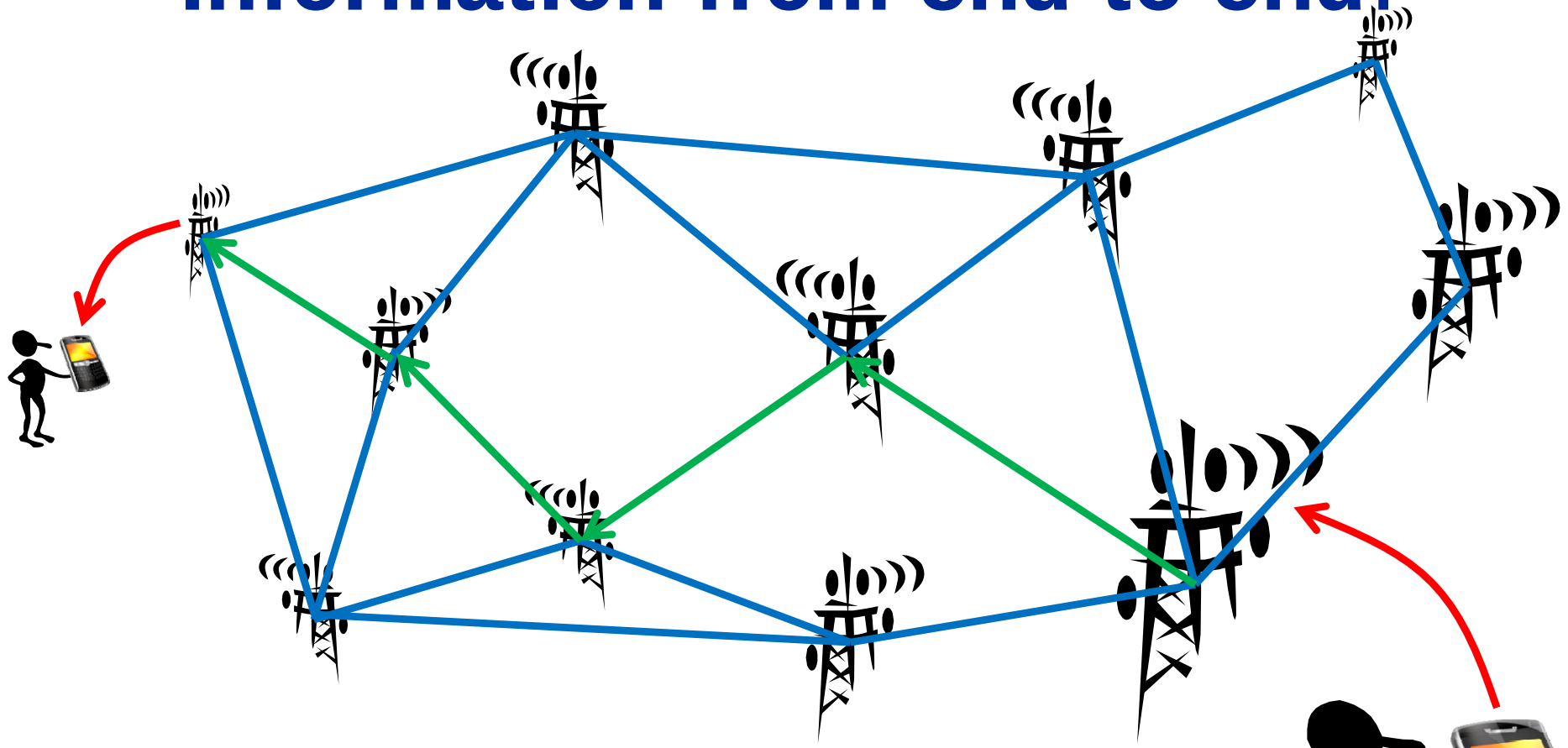
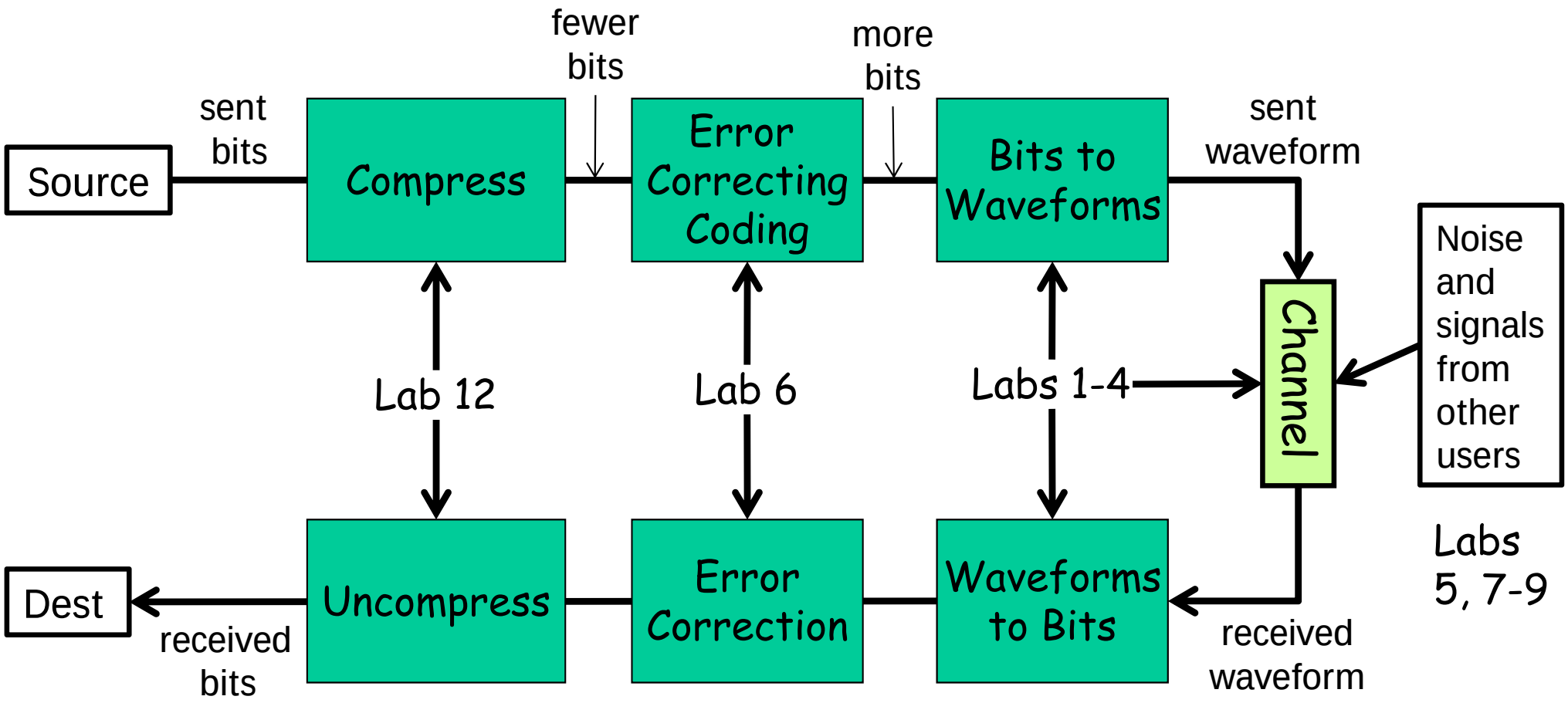


Point-to-point: point to point or node to node links first 2/3 of this course

Network: links between nodes last 1/3 of this course

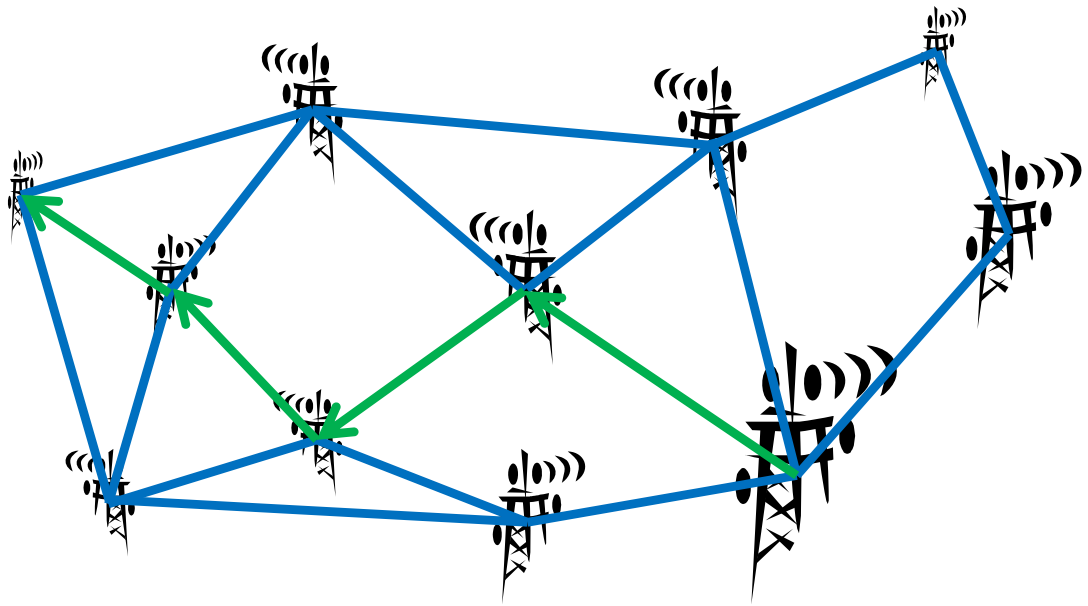
Point-to-Point Communication:



Labs 10-11?

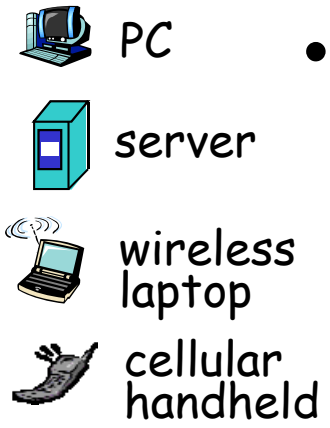
Network-connecting many users together

- A network allows us to connect many users together
- Consists of many point-to-point or node-to-node links

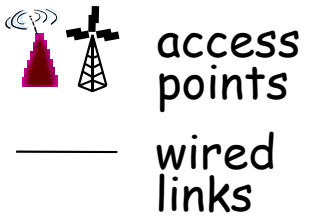


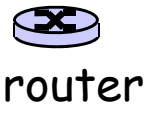
- In principle if there are N users there are N(N-1)/2 connections but this does not scale well to billions of users!
- Solution: Use a hierarchy of switches or networks

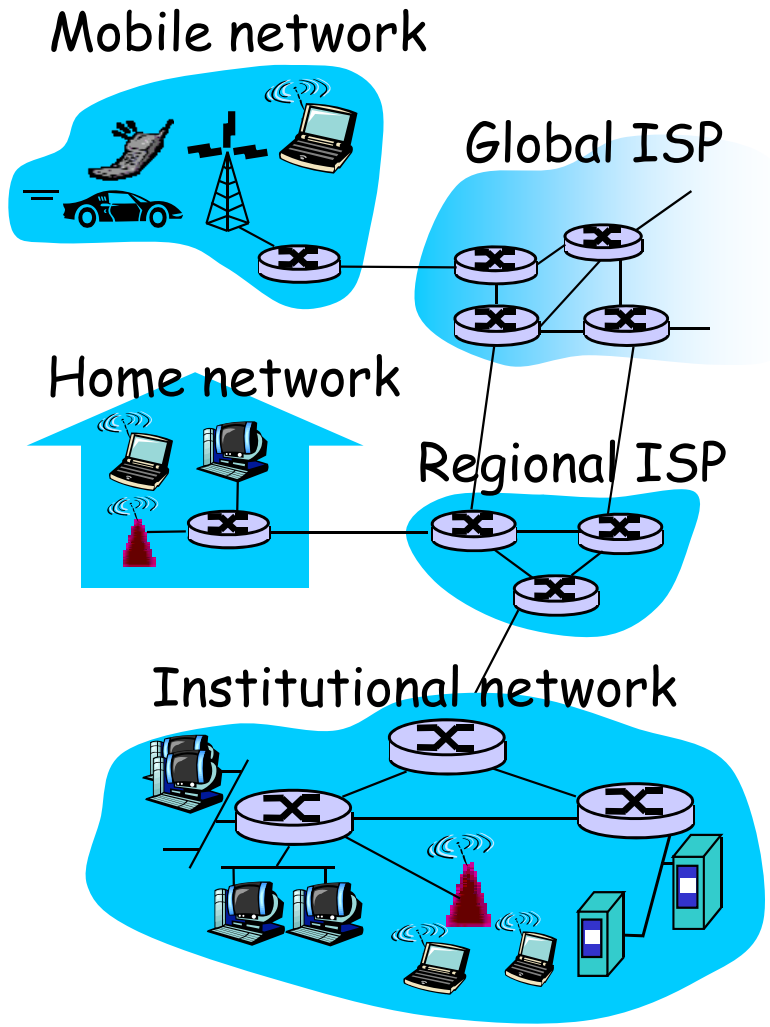
Internet- network of networks



- millions of connected computing devices: *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = *bandwidth*
- *routers:* forward packets (chunks of data)



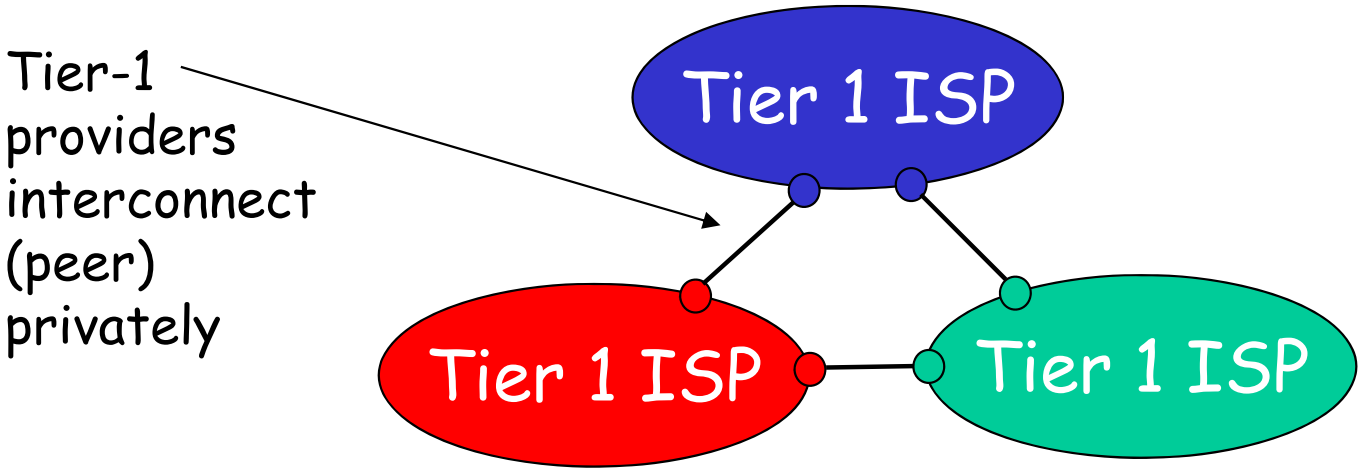




ISP: internet service provider

Internet: network of networks

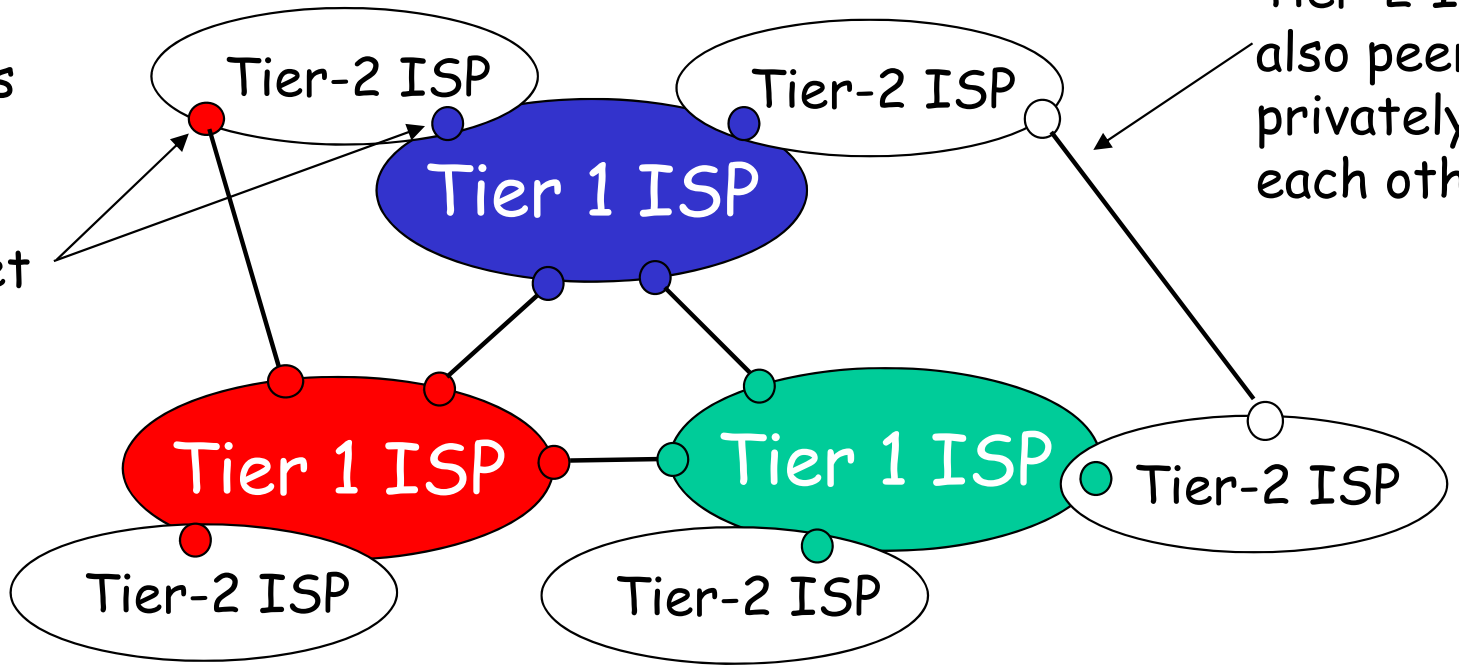
- roughly hierarchical
- at center: "tier-1" ISPs (e.g., Verizon, Sprint, AT&T, China Telecom), Global, national/international coverage
  - treat each other as equals



Internet: network of networks

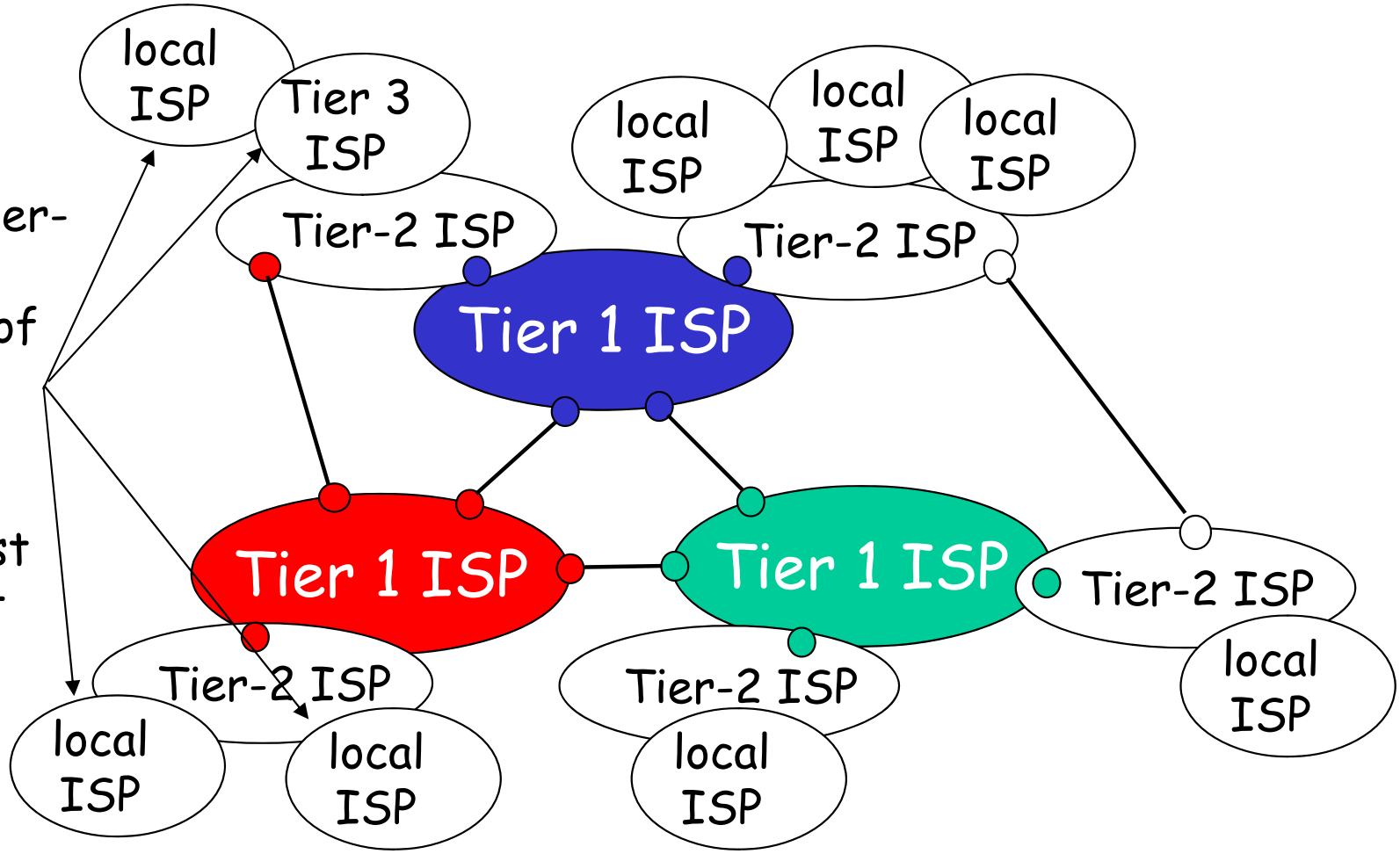
- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet
- tier-2 ISP is *customer* of tier-1 provider



Internet: network of networks

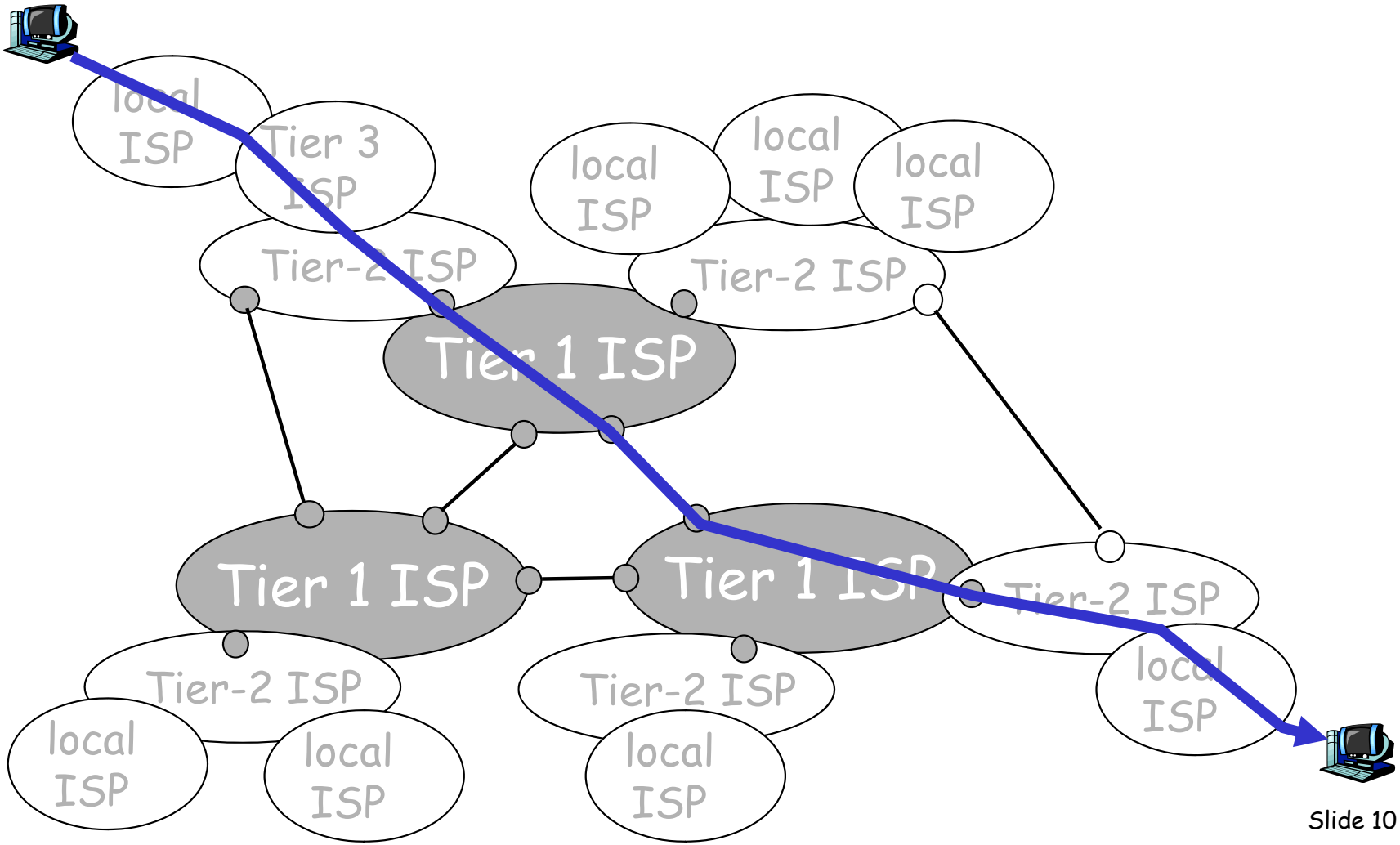
- "Tier-3" ISPs and local ISPs
  - last hop ("access") network (closest to end systems)



Local and tier-3 ISPs are *customers* of higher tier ISPs connecting them to rest of Internet

Internet: network of networks

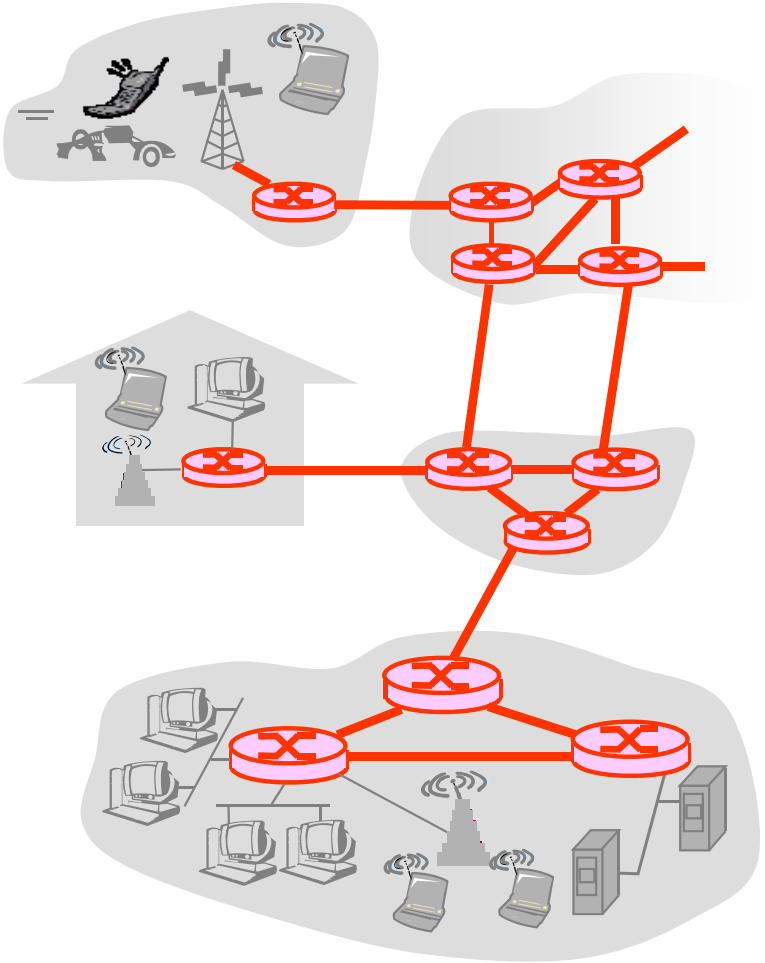
- a packet passes through many networks!



The Network Core

- Mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"

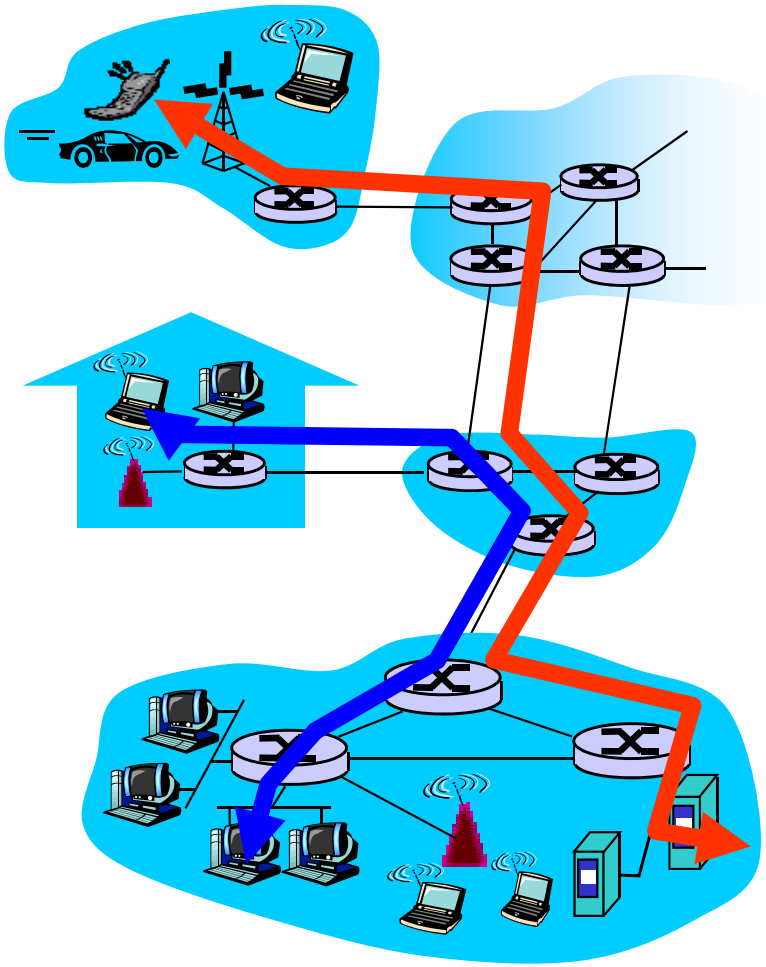
    (Phone networks also now moving to this model)



Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



network resources (e.g., bandwidth) divided into "pieces"

- frequency division multiplexing (FDM)
- time division multiplexing (TDM)

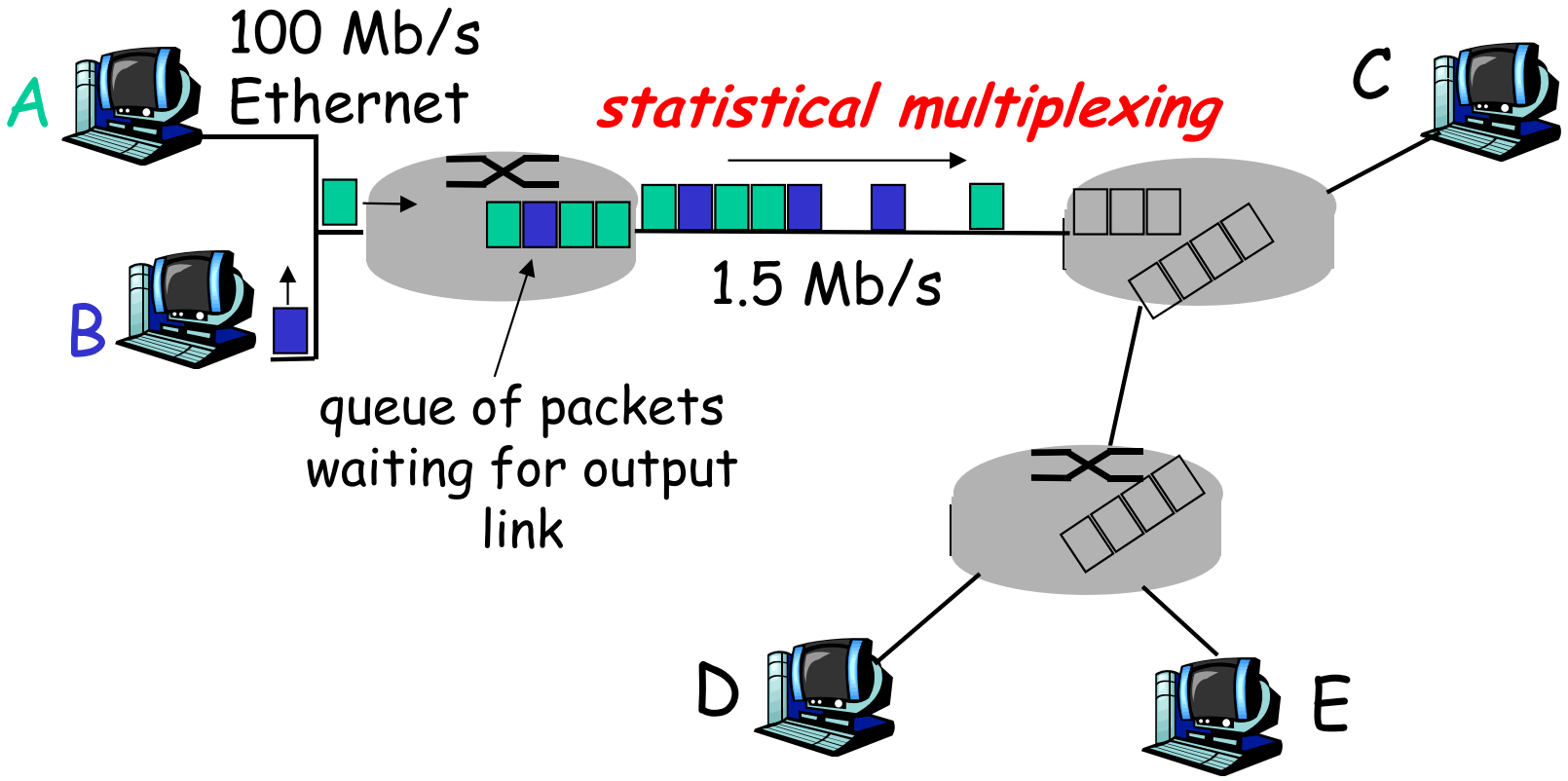
Network Core: Packet Switching

each end-end data stream divided into *packets*

- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*

- resource contention:
- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

Packet Switching: Statistical Multiplexing

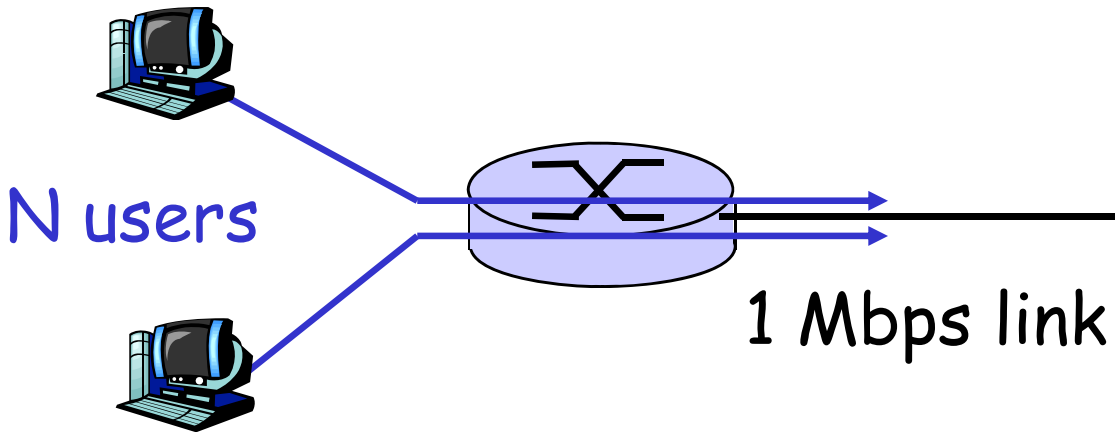


- Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand: ***statistical multiplexing***.
- In contrast, under circuit-switching using FDM, each host is allocated with a fixed frequency band.

Packet switching versus circuit switching

Packet switching allows more users to use the network!

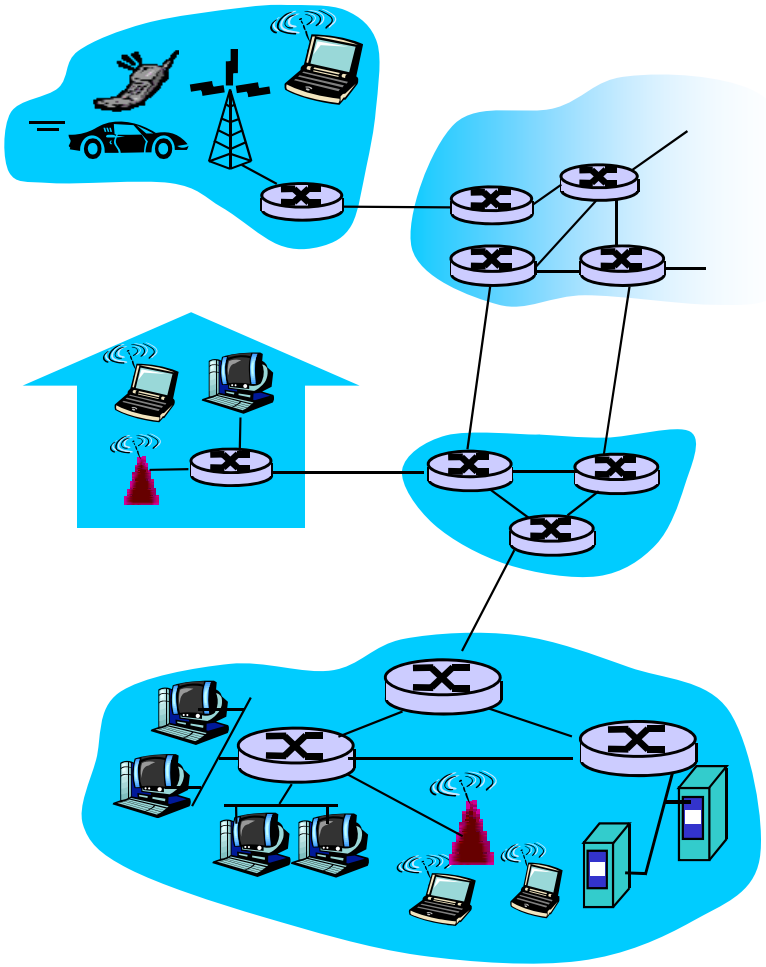
- 1 Mb/s link
- each user:
  - 100 kb/s when "active"
  - active 10% of time
- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004



$$\sum_{n=11}^{35} \binom{35}{n} p^n (1-p)^{35-n} \leq 0.0004$$

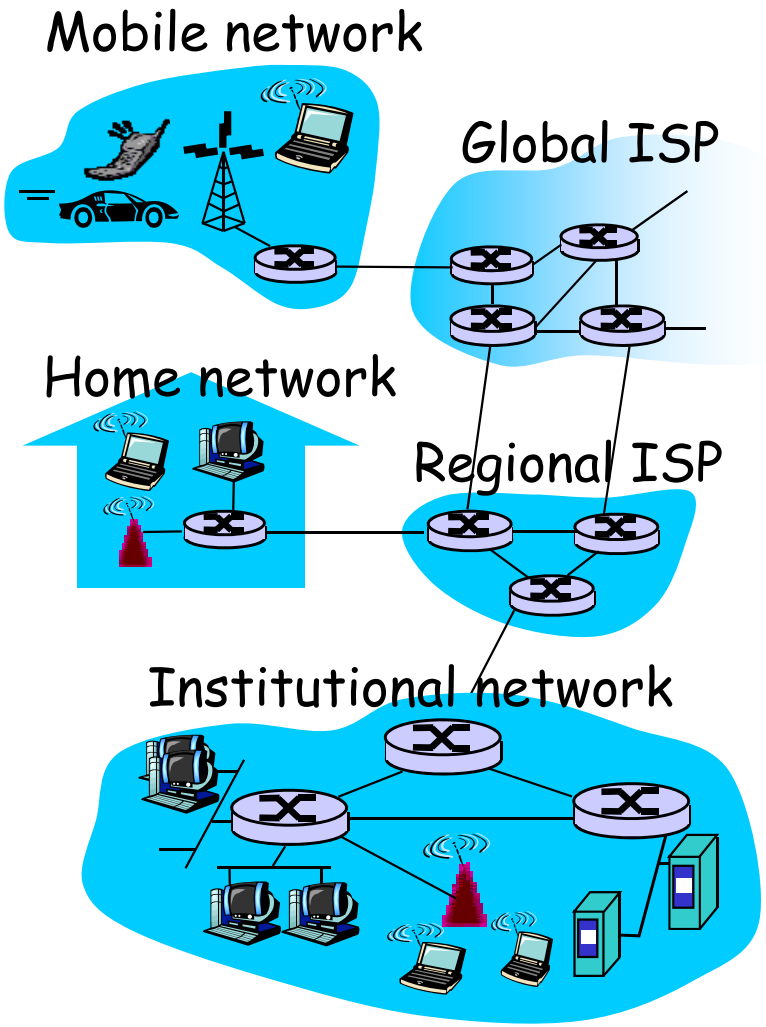
A closer look at network structure:

- network edge: applications and hosts
- access networks, physical media: wired, wireless communication links
- network core:
  - interconnected routers
  - network of networks



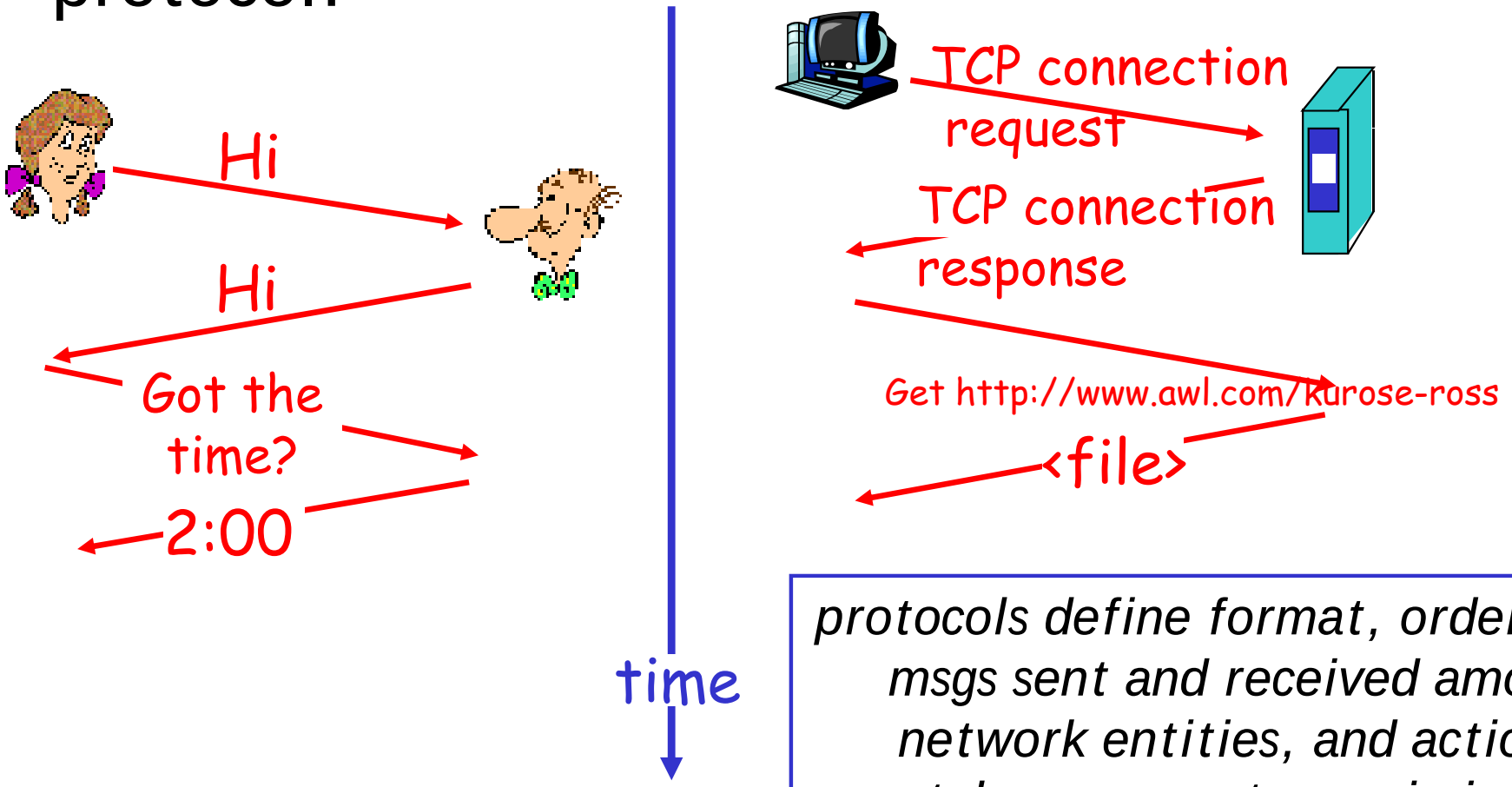
What's the Internet: "nuts and bolts" view

- *The individual connecting links: Utilizing Digital Modulation, Coding etc*
- *Protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet



What's a Protocol?

A human protocol and a computer network protocol:



protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

Q: Other human protocols?

Networks are complex!

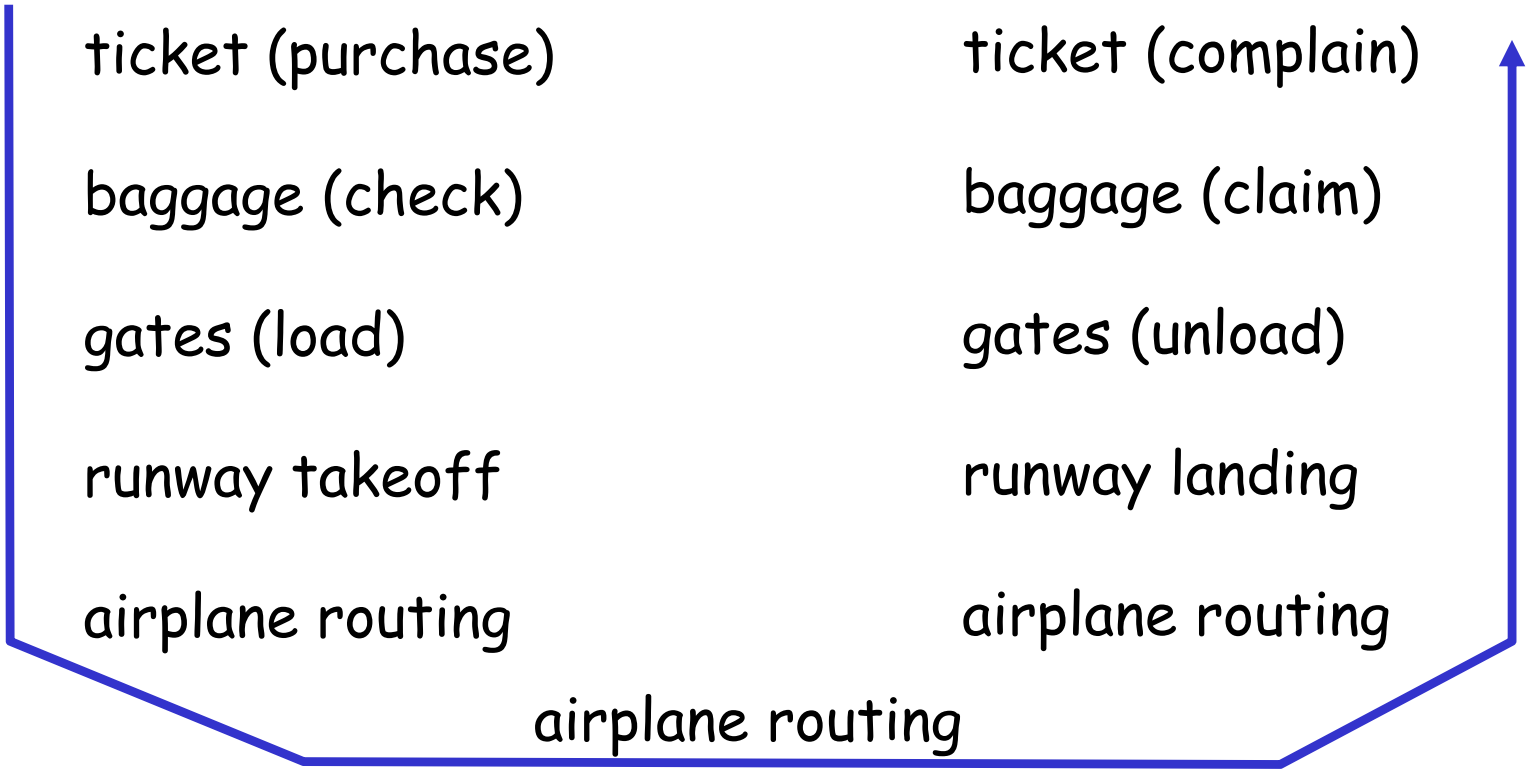
- many "pieces" or layers:
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

Is there any hope of *organizing* structure of network?

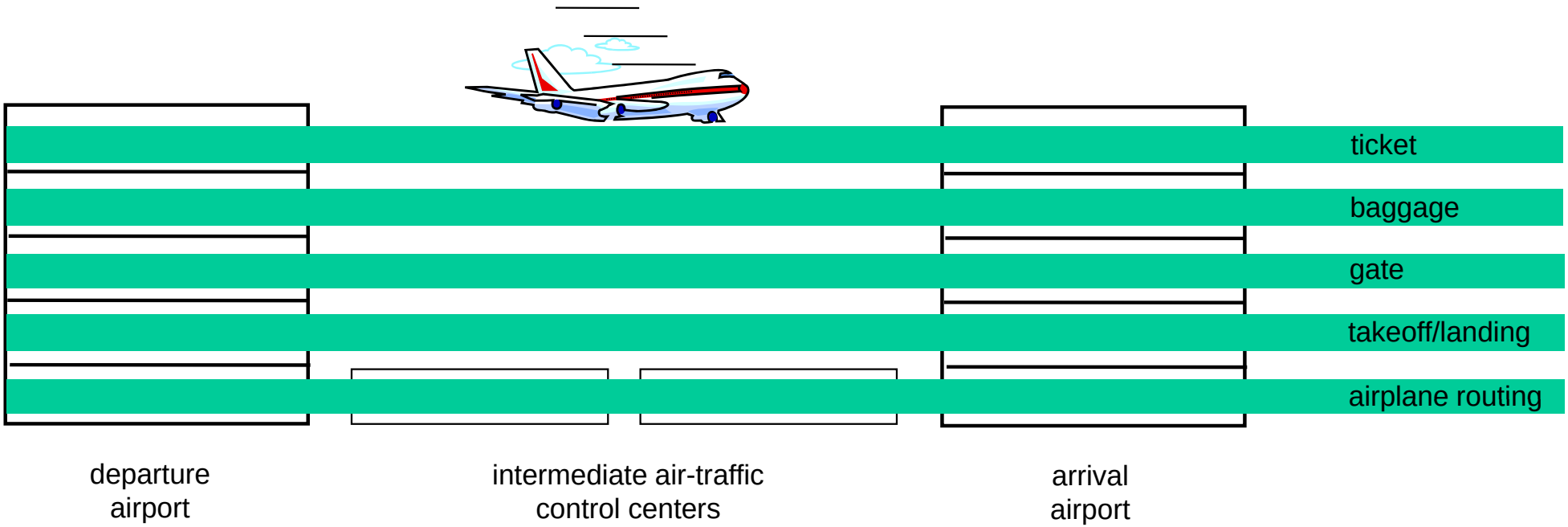
Or at least our discussion of networks?

Example of complex systems: Organization of air travel



- a series of steps

Layering of airline functionality



Layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

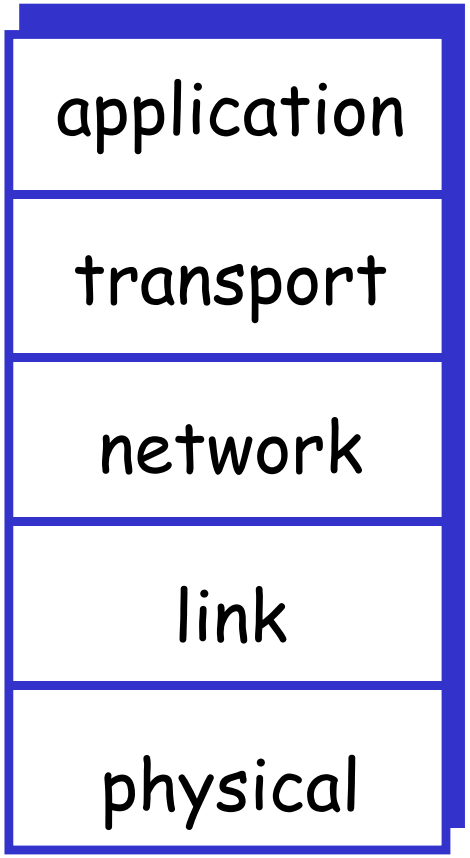
Why layering?

Dealing with complex systems:

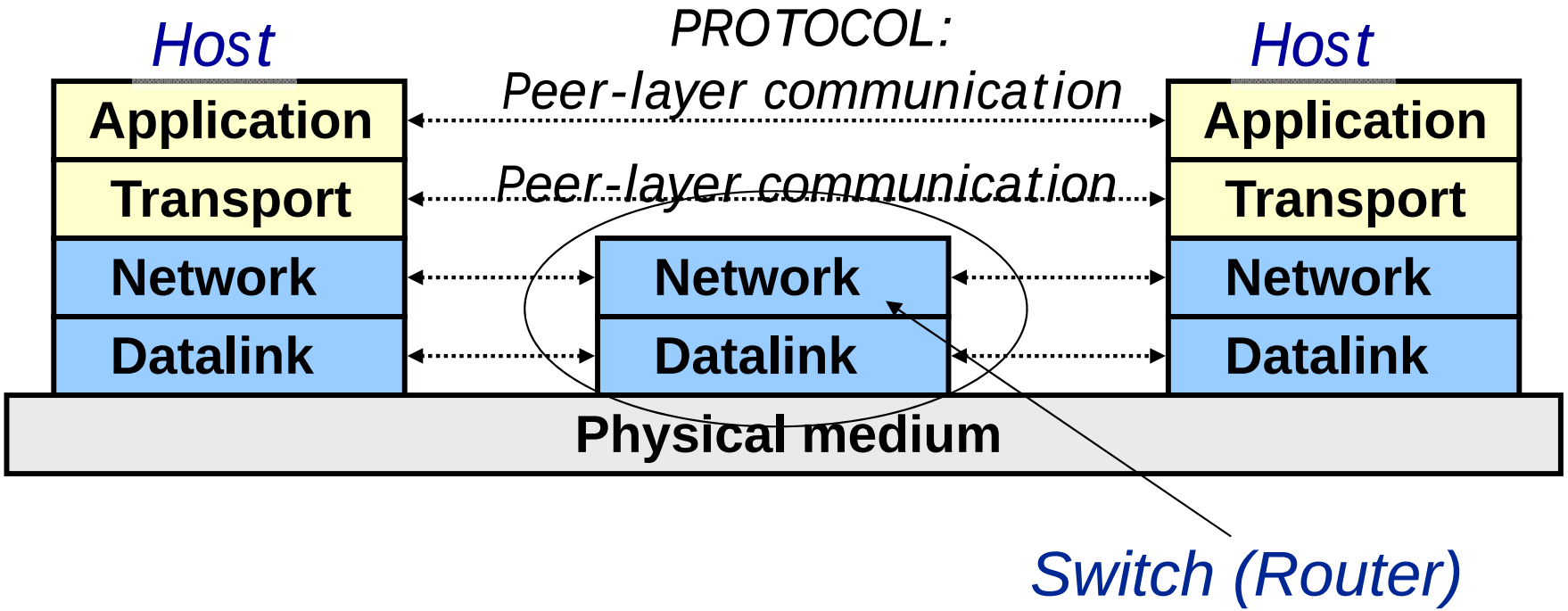
- *structure* allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- *modularization* eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

Internet protocol stack

- application: supporting network applications
  - HTTP, SMTP, FTP, DNS
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - 802.11, Ethernet
- physical: bits "on the wire"



Layering Interfaces



- Link and network layers are implemented everywhere
- The end-to-end layer (i.e., transport and application) is implemented only at hosts

Summary

- Networks use links to allow us to connect to other users and there are 4 key concepts introduced
- There are so many users that simple straight link connections does not scale
- 1- Therefore a hierarchy of switches is needed
- 2- The switches can be circuit or packet based but packet based allows statistical multiplexing and can be more effective
- 3- Protocols define how messages are sent
- 4- Because the network can be complicated a layered approach is utilized
- Each layer has a special function that is self contained and is a divide and conquer approach to the networking issue